ระบบผู้เชี่ยวชาญเพื่อทำนายน้ำท่วมฉับพลัน จากการพัฒนาพื้นที่เมือง

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บทคัดย่อ

การเกิดน้ำท่วมแบบฉับพลัน (Flash Flood) อันเนื่องมาจากโครงการพัฒนาในเขตพื้นที่เมืองนั้นเป็นปัญหาที่สำคัญ แม้ว่าจะเป็นการท่วมเพียงช่วงระยะเวลาสั้นๆ แต่ความรุนแรงของสภาพน้ำท่วมนั้นเพียงพอที่จะก่อให้เกิดผลกระทบในทางเสื่อมต่อสภาพแวดล้อม น้ำท่วมดังกล่าวนี้ไม่ได้เกิดจากปรากฏการณ์ธรรมชาติ แต่มีสาเหตุมาจากการละเลยการก่อสร้างระบบระบายน้ำที่เหมาะสมเพียงพอต่อการระบายน้ำฝนส่วนเกินออกจากพื้นที่ภายหลังการพัฒนาที่ดิน ระบบผู้เชี่ยวชาญเพื่อใช้ทำนายโอกาสน้ำท่วมนี้ได้ถูกพัฒนาขึ้นมาโดยใช้ซอฟท์แวร์ CLIPS (C Language Integrated Production System) ร่วมกับการประยุกต์ใช้สมการทำนายน้ำไหลบ่าแบบ Modified Rational Method โดยใช้ฐานข้อมูลจากรายงานการประเมินผลกระทบสิ่งแวดล้อมในประเทศมาเลเซีย เพื่อนำมาสร้าง rule-bases ดังนั้นการใช้ระบบผู้เชี่ยวชาญนี้ จะทำให้ทราบถึงปริมาณน้ำไหลบ่าซึ่งอาจก่อให้เกิดน้ำท่วมแบบฉับพลันในพื้นที่เมืองและบริเวณพื้นที่ใกล้เคียง เพื่อเป็นประโยชน์ในการจัดทำรายงานการประเมินผลกระทบสิ่งแวดล้อม และหามาตรการบรรเทาปัญหาอุทกภัยที่เหมาะสมมาประยุกต์ใช้ได้อย่างมีประสิทธิภาพ

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Expert System for Predicting Flash Flood due to Development in Urban Areas

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Abstract

Flash flood due to development projects in urban areas has been a significant problem in the world. Although the duration of flooding is short, it is sufficient to cause adverse environmental impacts due to its high intensity. All the floods occurring anywhere were not natural occurrences but caused by the negligence of developers in the construction of drains, which could channel excess rainwater after the land had been developed. An expert system for predicting flash flood was established by using CLIPS (C Language Integrated Production System). The Modified Rational Method for runoff estimation in urban areas, and knowledge derived from environmental impact assessment (EIA) reports submitted to the Department of Environment, Malaysia were incorporated in the rule-bases of expert system so that the expert system can predict the amount of flood that may occur in urban and vicinity areas. This expert system can be used as a tool in preparing EIA reports and EIA evaluations, therefore, the appropriate mitigation measures can be applied efficiently.

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1. Introduction

There is clear evidence from around the world that urban growth and flood problems go together. In the West Coast of Peninsular Malaysia where most of the major cities are located, flash floods are often encountered. A typical rainfall of about 2-4 inches is sufficient to cause a flash flood, which lasts about 3-g hours. Although the duration of flooding is short, it is sufficient to cause adverse environmental impacts because of its high intensity [1, 10]. Generally, in urban areas where land development projects are established, flash flood usually occurs as the most serious effect due to the lack of environmental protection incorporated during the construction period. After site clearing has been carried out, the construction site is prone to soil erosion because the cleared area is left barren [8]. The surface water runoff will also increase in amount and speed, especially when the developers do not follow recommendations made by the Drainage and Irrigation Department (DID) to construct adequate drainage for the discharge of rainwater from their project site to the main river outlets. Furthermore, they do not build proper silt traps for preventing siltation that can block waterway of drainage systems. Consequently, the rainwater strips away the topsoil and the mud water flows down to low-lying areas where flooding occurs eventually [5,13]

The objective of this study is to develop a comprehensive expert system that could be used as a tool for predicting flash flood due to development activities and for helping users in preparing environmental impact assessment (EIA) reports.

2. Flood estimation

Flood estimation procedure, which has been used for many urban areas in Peninsular Malaysia (cf. EIA reports), is a modified form of the Rational Method analysis. The analysis takes into consideration the effect of channel storage on peak runoff estimation [3, 4]. The standard Rational Method is usually expressed in terms of the following equation:

$$Q_p = CIA$$

To account for channel storage, an additional storage coefficient (C_s) has been added to obtain the modified form of the Rational Method as follows:

$$Q_p = C_s CIA$$

where; Q_p is the peak discharge in ft^3/sec, C is the runoff coefficient, C_s is storage coefficient, I is rainfall intensity in in/hr for a duration equal to the time of concentration (t_c) and return period, and A is the catchment area in acre. The storage coefficient, C_s can be derived as follows:

$$C_s = 2t_c / (2t_c + t_d)$$

where; t_c is time of concentration in minute:

A review of the literature revealed many empirical formulas for estimating the time of concentration. Most however are on local conditions. For urban areas in Peninsular Malaysia, it is recommended that the time of concentration can estimated from the sum of the overland flow time (t_o) and the time of flow in the drain (t_d) [3].

$$t_c = t_0 + t_d$$

= The time required for the water to flow from the most remote point of the catchment to the point being investigated.

The capacity of the drain which the runoff will flow (Q_c) can be calculated using the Manning's Formula [4].

$$Q_c = (1.49/n)\, AR^{2/3} S^{1/2}$$

where; Q_c = Water flow (ft^3/sec), n = Manning's roughness coefficient (recommended value for drain lined with vegetation = 0.35, for drain lined with concrete = 0.017), A = Area of cross-section (ft^2), P = Wetted perimeter (ft), R = A/P = Hydraulic Radius (ft), S = Slope (ft/ft)

3. Expert system

Expert system refers to a category of computer programmes that are encoded with and apply the knowledge of specific areas of expertise to provide solutions to problems within specialised domains of understanding. As a problem-solving device, an expert system interprets information and reasons toward a conclusion obtaining the same results that the human expert would arrive at if presented with a comparable task [6]. An expert system consists of three basic components. The first component is the knowledge base, which contains information on facts, definitions, heuristics and computational procedures applicable to the problem domain. The second component is the ***inference*** engine, which drives the knowledge base through reasoning processes, which are similar to those of a human expert. The third component is user ***interface,*** which is the means by which the user communicates with the knowledge base. It allows the user to question the expert system and for the system to provide answers and clarification on points which may be unclear to the system user [6, 9, 12].

4. CLIPS

CLIPS or the C Language Integrated Production System is a forward chaining production system written in ANSI C and developed in 1984 at the NASA (National Aeronautics and Space Administration) Johnson Space Centre, USA. The CLIPS provides a cohesive tool for handling a wide variety of knowledge with support for different programming paradigms namely rule based, object oriented or procedural [2]. Rule based programming allows knowledge to be represented as heuristics, which specify a set of actions to be performed for a given situation [7]. According to Loh et al. [11], heuristic rule-bases can be selected and applied for various projects. The results generated by these rule-bases are stored in database and are used to assist in decision making.

5. Materials and Methods

A study was carried out on environmental impact assessment (EIA) reports submitted to the Department of Environment (DOE), Malaysia. 100 of the EIA reports were taken randomly and studied for flash flood problems in urban areas due to the effect of project activities. An expert system was established and based on the knowledge derived from EIA reports by programming in CLIPS. For predicting the amount of peak discharge that would cause flash flood, the Modified Rational Method for application in urban areas of Peninsular Malaysia was incorporated in the rule-bases of the expert system, and the capacity of the drain could be calculated by Manning's Formula.

6. Results and Discussion

6.1 Knowledge derived from EIA reports

A study of 100 environmental impact assessment reports (Table 1) indicates that although 30% of the reports discussed flash flood problems, only 18% have reported flood estimation methods using the modified form of the Rational Method and 28% have discussed mitigating measures. Although there were some reports presenting flash flood problems and recommended mitigating measures, they did not mention about the estimation method. Some reports stated that the increase in runoff from the surrounding catchments is large and has some potential consequences on the project area. The lack of information on the drainage systems in the area and also information on its topography make it difficult to predict any impact and evaluation of the project activities and its surroundings since the direction of runoff can not be used to predict the impact with more accuracy.

Table 1 Summary of 100 EIA reports submitted to DOE

Project Activities	Number of Selected EIA Reports	Flash Flood Discussed	Flood Estimation Discussed	Mitigation Discussed
Housing	36	8 (22%)	2 (6%)	6 (17%)
Resort and Recreation	20	4 (20%)	0 (0%)	4 (20%)
Infrastructure	18	10 (56%)	8 (44%)	10 (56%)
Industry	8	4 (50%)	4 (50%)	4 (50%)
Mixed Development	14	4 (29%)	4 (29%)	4 (29%)
Sewerage Development	2	0 (0%)	0 (0%)	0 (0%)
Drainage and Irrigation	2	0 (0%)	0 (0%)	0 (0%)
TOTAL	100	30 (30%)	18 (18%)	28 (28%)

6.2 Expert system flowchart

The main flowchart of expert system applied for predicting flash flood is presented in figure 1.

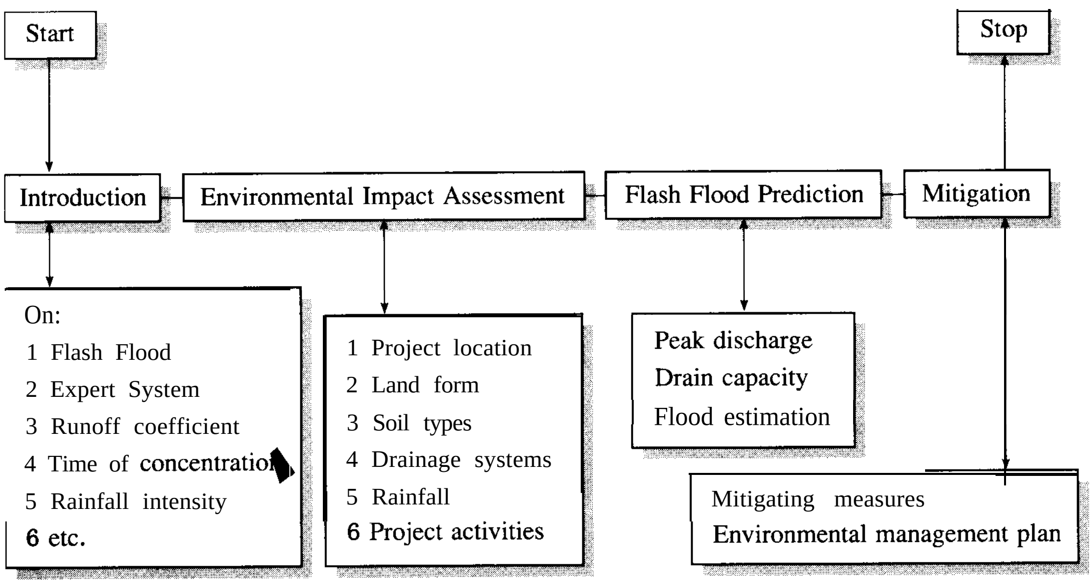

Figure 1 The **main flowchart of the expert system for predicting flash** flood in urban areas

0.3 Expert system rules

The expert system will come in the form of "IF- *THEN*". An example of the set of rules is shown as follows :

```
(defrule read-input)
(initial-fact)
=>
(printout t "How long is the stream length to the design point? feet" crlf)
(bind ?l (read)= 3000)
(printout t "What is the slope? %" crlf)
(bind ?v (read)= 4)
(printout t "How long is the time of overland flow? (time of over land flow read from graph by loading picture file) minutes" crlf)
(bind ?tO (read)= 22)
(bind ?td (/ ?l (* ?v 60 )))
(bind ?tc (+ ?tO ?td ))
(printout t "tc value=" ?tc "minutes" crlf)
(printout t "How much rainfall intensity is there at the project site? (rainfall intensity read from graph by loading picture file under tc value and a return period) in/hr" crlf)
(bind ?i (read)= 4.2)
(bind ?cs (/ (* ?tc 2) (+ (* ?tc 2) ?td )))
(printout t "cs value=" ?cs crlf)
(printout t "What is the type of land use? (to get C, runoff coefficient value" crlf)
(bind ?c (read)= 0.90)
(printout t "How big is the catchment area? acre" crlf)
(bind ?a (read)= 650)
; result
(bind ?q (* ?cs ?c ?i ?a ))
(printout t "Qp value (peak discharge) =" ?qp = 2088 "cusecs" crlf))
```

(defrule prediction "Rule to predict flash flood"

(= ? ***qc*** drain capacity by Manning's Formula 1000)

(> ?qp 1000)

=>

(message-box "FLASH FLOOD PROBLEM MUST BE CONSIDERED [Peak Discharge > Drain Capacity]. THE CAPACITY OF DRAIN IS NOT ENOUGH TO DRAIN AWAY STORM WATER RUNOFF. *GO TO MITIGATION*" wxok 0 0 "evaluation"))

Translation :

IF ***Data are read from facts***

THEN ***L value (stream length to design point) = 3000 feet***

V value (velocity of flow) = 4 *feet/sec*

t_o value (time of over land flow read from graph) = 22 minutes

I value (rainfall intensity read from graph ***for a*** duration equal to t_c and ***a return period) = 4.2*** *inches/hr*

C value (runoff coefficient developed ***for*** urban areas in Peninsular Malaysia ***under different types of land use) = 0.90, Business City Areas***

A value (Drainage Area or Catchment Area) = 650 acres

RESULT:

Q_p ***value (Peak Discharge) = 2088*** ft^3/sec

RULE TO PREDICT FLASH FLOOD:

IF Q_c Drain Capacity calculated by Manning's Formula = $1000\ ft^3/sec$

AND Q_p ***value (Peak Discharge) > 1000*** ft^3/sec

THEN ***FLASH FLOOD PROBLEM MUST BE CONSIDERED BECAUSE THE RESULT*** HAS SHOWN THAT THE CAPACITY OF DRAIN IS NOT ***ENOUGH TO DRAIN AWAY THE PEAK DISCHARGE OF STORM WATER RUNOFF GO*** **TO MITIGATION**

6.4 User Interface

The users can use the screen and the keyboard to interface with the system. The expert system will ask the user with the questions and display the set of possible answers to be selected as shown in the list below:

Question 1.

How long is the stream length to the design point?

Answer:

The answers are *the* independent variables. Users can input data by real number.

Question 2.

What is the slope? Please select a choice number in the bracket.

Answer.'

(1) slope *1-2%*	flow velocity = 2 *ft/sec*
(2) slope *2-4%*	*flow* velocity = *3 ft/sec*
(3) slope *4-6%*	*flow* velocity = 4 *ft/sec*
(4) slope 6-10%	flow velocity = 5 *ft/sec*
(5) slope *10-15%*	flow velocity = 8 *ft/sec*

Note: Slope and velocity values are given by DID [3]

Question 3.

How long is the timé of overland flow?

Answer.'

The answers are *the* independent variables Users can input data read from graph, which will be shown on screen by loading picture tile.

Question 4.

How much rainfall intensity is there at the project site?

Answer.'

The answers are the independent variables. Users can input data read from graph related to urban area where the development project is set up, using duration equal to t_c and a return period. The graph will be shown on screen by loading picture file.

Question 5.

What is the type of land use? Please select a choice number in the bracket.

Answer:

	Land Use	Runoff Coefficient (C)
(1)	Business city ***area*** fully built-up	***0.90***
(2)	Industrial area fully built-up	***0.80***
(3)	Residential area 4 houses/acre	***0.55***
(4)	Residential area 4-8 houses/acre	***0.65***
(5)	Residential area 8-12 houses/acre	***0.75***
(6)	Residential area 12 houses/acre	***0.85***
(7)	Pavement	***0.95***
(8)	Park (normally ***flat in*** urban areas)	***0.30***
(9)	Rubber	***0.45***
(JO)	Jungle (normally ***steep in*** urban areas)	***0.35***
(J J)	Mining land	***0.10***
(12)	Bare ***earth***	***0.75***

Note: Runoff coefficient developed for urban areas in Peninsular Malaysia [3,4]

Question 6.

How big is the catchment area?

Answer:

The answers are independent variables. User can input data by real number.

0.5 Example screen for data input

For data input, expert system developed will show various screens so that user can input data easily. An example screen for questions 4-6 is shown in Figure 2.

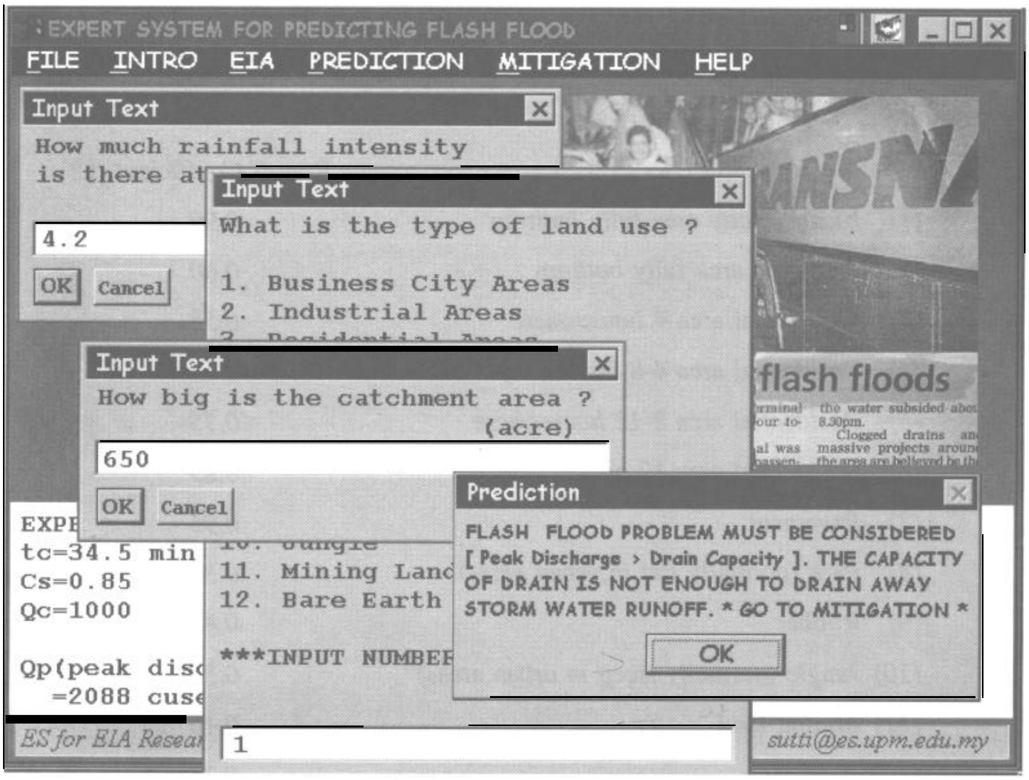

Figure 2 A screen showing the set of questions 4,5,6 and a message box of prediction.
The user answers questions by inputting numbers and selecting choices displayed on screen.

6.6 Screen Explanation

As shown in Figure 2, to evaluate peak discharge, user can select PREDICTION menu and input data by answering questions given by the expert system. To save and print out the results of prediction, user can select FILE menu. To get information of flash flood, EIA, and mitigating measures, user can select INTRO, EIA and MITIGATION menu respectively. Expert system inference engine will incorporate, interpret data and display the results in message boxes of the screen. Some parameters calculated by expert system (t_c, C_s, Q_c, Q_p) will be displayed on window text area of the screen.

Regarding flash flood prediction, to estimate the change of peak discharge before and after development, users have to concern about the land use types because the change of land use from present to ultimate land use generally increases the runoff coefficient (C) directly. For example, if the drain capacity (Q_c) is 1000 ft^3/sec, the existing land use at the project site before development is a park **(C = 0.30)** and the ultimate expected development is a business city area (C = 0.90). In case of t_c, C_s, I, and catchment area shown in Figure 2, peak discharge should be 696 ft^3/sec before development, thus, there will be no flooding problem because the existing drain is enough to drain away the storm water runoff. However, after the conversion of the park area into the business city area, peak discharge would be 2088 ft^3/sec (Q_p increase 1392 ft^3/sec). In this way, the flood situation can not be avoided. Consequently, appropriate mitigating measures should be applied properly to prevent flooding problems that may occur due to activities of development projects. Using this expert system recommended mitigating measures would be display on window text area by loading text file after clicking MITIGATION menu.

7. Conclusion

Environmental impact prediction, evaluation, and mitigation are the heart of environmental impact assessment (EIA) process. Urban development may have impacts on the physical environment, particularly, flooding problems. For flash flood prediction, the expert system is useful to estimate flooding that may occur due to any development under the different project activities and their environments. The expert system developed can be used as a decision making tool in preparing EIA reports for protecting environments from any adverse impacts. It would be also applied to recommend some appropriate mitigation and abatement measures to minimise adverse impacts. It is hoped that this expert system can reduce the occurrence of flash flood, a serious problems in urban areas.

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